Rockets – Motors

By Dale Waldo - 2015

Subject Area: *PLTW Flight and Space* **Grade Level:** *6, 7 and 8th* **Date:** 8/4/15

- ❑ **Abstract Lesson Overview**

Introduction

Propulsion is the way in which spacecraft are pushed into space based on Newton's laws. It is a combination of factors such as thrust (forward push), lift (upward push), drag (backward pull), and weight (downward pull). In order for a spacecraft to achieve forward motion, it must have enough thrust and lift to overcome drag and weight. Different propulsion systems produce thrust in different ways.

The aerodynamics of space vehicle flight is based on the effects of Earth's gravity and the availability of oxygen in the atmosphere. Low Earth orbit and beyond space flight is much different since it must break through the gravitational pull and oxygen is absent in space. Engineers had to develop an alternative type of propulsion that could develop thrust without burning oxygen.

All of the engines force a gas to shoot out of the rocket, thus pushing the rocket in the opposite direction. For every action there is an equal and opposite reaction.

In this project you will work as a team member to mix and deliver solid rocket fuel propellant, design a new solid fuel rocket to include the fuel containment vessel (fuel tank), insulation for the fuel tank/propellant burn tank, exhaust nozzle and all coupling to attach all components together.

- ❑ **Instructional Materials Needed**

Equipment

- 3D CAD software – engine design must be compatible with 3D printer
- 3D Printer
- Propellant materials – Sugar, stump killer
- Heating source to caramelize the solid fuel
- Frying Pan to heat and mix the fuel components
- Thin cork material for insulation (fuel tank and nozzles)
- Tin foil for insulation (fuel tank and nozzles)
- Heat resistant silicone materials (fuel tank and nozzles)
- Paper towels (for clean-up at launch site)
- Eye protection
- Stop watch
- Calculator
- Measuring spoons

- [ ] **Instructional Materials Provided**

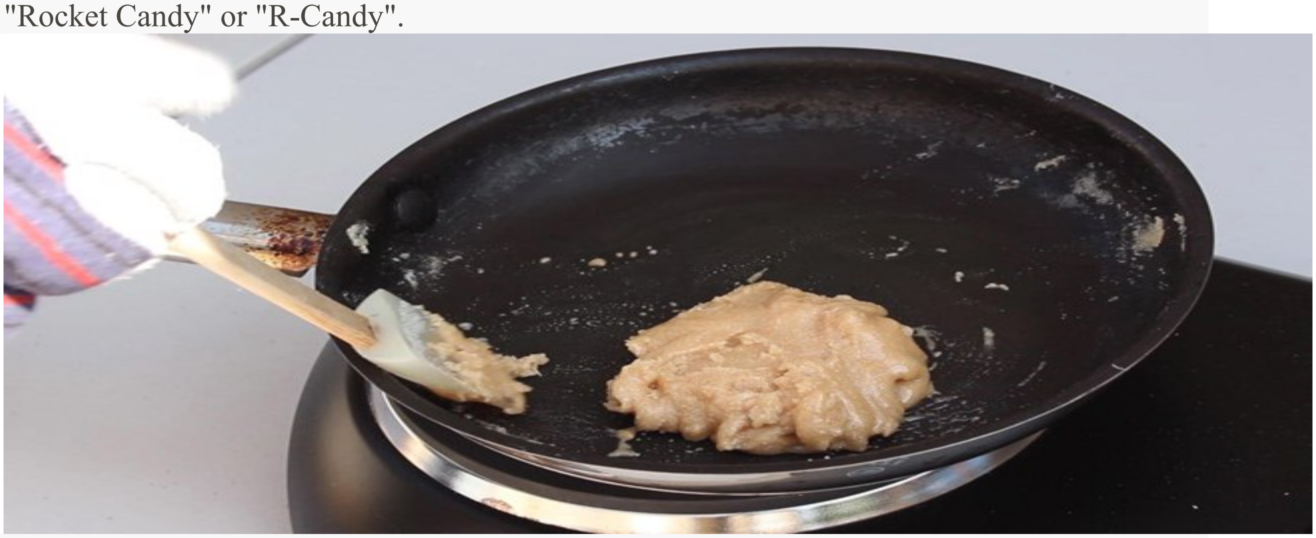
Procedure

1. Design the following items on your 3D CAD software:
    a. Design Rocket engine fuel containment vessel (Fuel tank)
    b. Design Rocket engine exhaust nozzles (how many?).
    c. Design a part or have couplers on the fuel tank and nozzles to connect the two parts so they cannot separate during ignition or fuel burn.
    d. Design a "Casting Core" (will make an imprint in the solid rocket fuel of the fuel burn design (more surface area creates a faster burn with more thrust).
    e. Save all three files as .stl files and print items a, b and c on the 3D printer to specification.
2. Insulate the inside of the fuel tank and all nozzles with a layer of cork material covered by a layer of tin foil.
3. Make an adequate amount of caramelized solid rocket fuel. While the fuel is still soft, pack enough into the open end of the fuel to fill it ¾ full.
4. The recipe for the solid rocket engine fuel is as follows:

- Using some kitchen chemistry and a few common household items, you can mix a solid rocket that will produce the necessary thrust.
- 

- The main components of this composition are a brand of stump remover, which is 100% potassium nitrate (KNO3), and plain white table sugar

- When mixed together in ratios of 60/40 by weight, and placed on medium heat, they melt into a creamy brown liquid. This is because the sugar caramelizes and absorbs the KNO3. The smell is similar to that of making candy, and that's why this is sometimes referred to as "Rocket Candy" or "R-Candy".



- When it's runny enough, it can be poured into a casing to cool down and solidify. I'm using these Mega-Block LEGOs. Watch out, it's hot!

- 
- I tried some more batches with other ingredients added, like water, corn syrup and even a little homemade rust powder.
    - 

1. While the solid fuel is still soft (act quickly), press the Casting Core into the soft solid rocket fuel to create the imprint/shape of your Casting Core in the material.
2. Attach your nozzle/s to the Fuel tank, make sure all cork and foil insulation is in the proper places and secure. See these links for cork insulation information:
   http://www.google.com/patents/EP0359455B1?cl=en
   http://www.nasa.gov/centers/johnson/pdf/584728main_Wings-ch4b-pgs182-199.pdf

   All rockets assembly parts – Fuel Tank, Nozzle/s, Casting Core and all parts must be ready for use before the solid rocket fuel is mixed. The solid rocket fuel must be packed into the tank and “Plunged” using the Casting Core while the fuel mixture is still soft.

❑ **Expected Student Outcomes**

1. Students will master the skills needed to create boosters, nozzles and plunge casts in Autodesk inventor.
2. Students will master the skills needed to create solid rocket fuel.
3. Students will master the skills needed to make and implement an effective plunge cast in their solid fuel rocket motors.

4. Students will experiment and determine what happens when you ignite the solid rocket fuel.
5. Students will design a useable test bed for their solid fuel rocket motors.
6. Students will design and test their solid fuel rocket motors in both rocket cars and vertical launch rockets.
7. Students will gather data to determine the effectiveness of their designs.

- ❑ **Student Deliverables**

  - o Verified design in Auto desk Inventor of the following:
    - ▪ Rockets Booster (fuel containment vessel), Engine Nozzles to attach to the Booster Fuel Tank and the Plunge Cast.

    Parts Verified to specification as follows:
    - ▪ Rockets Booster (fuel containment vessel), Engine Nozzles to attach to the Booster Fuel Tank and the Plunge Cast.

    Test Bed design and fabricated Test Bed for the Solid Fuel Rocket Motor.
    Rocket Car and Vertical Launch Rocket designs and complete fabricated Cars and Rockets.
    Test Data and conclusion Questions answers.

Conclusion Questions:

1. How did you determine your initial design using the Design Process?
2. How did you translate your ideas to your Inventor designs?
3. How smoothly did your transition from Inventor to 3D printing go? Describe what went well and what did not go so well.
4. Experiment and determine what happens when you ignite the solid rocket fuel on the Test Bed and in other trials (Rocket Cars and Vertical Launch Rockets)?
   - i. What is the goal of your test?
     1. Burn time
     2. Thrust generated
     3. Payload lift
   - ii. Based on the goal of your test, was it successful?
   - iii. If not successful, what do you need to change in your design?

5. What is the "Burn" time?

6. What is the thrust created?

7. What is the amount of lift? How heavy of a payload can it carry?

8. Calculate the total cost of your fuel propellant mixture.

9. Calculate the total cost of your total project.

- **Cost of Lesson**: $1,000
    - 2 Robo 3D Printers
    - Filament
    - Cork Insulator Material
    - Silicone Insulator
    - Rocket Fuel Ingredients

- **Duration of Lesson:** *10* Days

Culminating Activity and/or Assessment

- Testing of the solid fuel rocket motors will be done on a static test stand first.
- Students will design and fabricate both rocket powered cars and actual vertical flight rockets.

- **Enrichment Suggestions**
    - Students should be encourage to design actual Rockets that will be launched to determine what design will reach the highest altitude.

- **Additional Resources**
    - http://www.google.com/patents/EP0359455B1?cl=en

http://www.nasa.gov/centers/johnson/pdf/584728main_Wings-ch4b-pgs182-199.pdf

http://www.grc.nasa.gov/WWW/K-12/airplane/ngnsim.html

http://www.gefs-online.com/

http://www.flightsim.com/

http://flyawaysimulation.com/downloads.html

- **CTE Pathway Standards**

PATHWAY STANDARDS A. Aviation and Aerospace Transportation Services Pathway The Aviation and Aerospace Transportation Services Pathway prepares students for postsecondary education and employment in the aviation and aerospace industries. A1.0 Students understand the value and necessity of practicing personal and occupational safety and protecting the environment by using materials and processes in accordance with manufacturer and industry standards: A1.1 Practice fundamental, application-specific work processes, safety concepts, and required behaviors. A1.2 Practice fundamental, application-specific biological health-hazard safety concepts and required behaviors. A1.3 Understand the generation of waste gasses, emissions, and other environmentally destructive gasses and substances and the effect of such substances on the environment. A1.4 Understand the advantages and disadvantages of aviation and aerospace transportation systems and the effects of those systems on the environment. A1.5 Understand new and emerging aviation and aerospace transportation energy systems, materials resources, and technology (e.g., carbon fiber) and the related implications on the environment. A1.6 Understand the elements of combustion, fire classifications, and fire-fighting equipment and techniques specific to the aviation and aerospace industries. A2.0 Students understand the safe and appropriate use of tools and equipment common to the aviation and aerospace industries: A2.1 Understand how aviation/aerospace industry tools and equipment are used to perform systems and component maintenance and repair operations. A2.2 Understand current industry practices and strategies for work processes. A2.3 Use appropriate tools, equipment, and machines common to aviation/aerospace components and systems. A2.4 Use tools, equipment, and machines to safely measure, test, diagnose, and analyze aviation/aerospace components and systems (e.g., electrical and electronic circuits, alternating- and direct-current applications, fluid/hydraulic, and air/ pneumatic systems). A3.0 Students understand and apply measurement systems and the mathematical functions necessary to perform required maintenance and operation procedures: A3.1 Understand industry-standard measurement scales, devices, and systems used to perform design, fabrication, diagnostic, maintenance, and repair procedures. A3.2 Use technical vocabulary, technical reports and manuals, electronic systems, and related technical data resources specific to components and systems in the aviation/aerospace transportation industry. 356 Aviation and Aerospace Transportation Services Pathway A3.3 Understand the importance of calibration processes, systems, and techniques in using various measurements and testing devices. A3.4 Understand the mathematical functions associated with the production and maintenance of aircraft. A3.5 Understand mathematical functions at a proficiency level specified by Federal Aviation Administration Regulations, Part 147, Appendix B. A4.0 Students understand scientific principles in relation to chemical, mechanical, and physical functions: A4.1 Understand the operating principles of internal and external combustion engines. A4.2 Understand the basic principles and the applications of pneumatic and hydraulic power. A4.3 Understand the potential application of alternative power sources. A4.4 Understand the basic principles of electricity, electronics and electrical power generation, and distribution as commonly applied. A4.5 Understand the principles of converting energy from one form to another and their applications. A4.6 Know the basic terms, characteristics, and concepts of physical and chemical processes. A5.0 Students understand and perform maintenance procedures for aviation and aerospace vehicles: A5.1 Understand electrical applications, weight and balance specifications, and drawings and schematics at the proficiency level specified by Federal Aviation Administration Regulations, Part 147, Appendix B. A5.2 Understand fluid lines and fittings, materials and processes, ground operation and servicing, cleaning and corrosion control, and maintenance forms and records at the specified proficiency level. A5.3 Know the conditions under which service and maintenance are required for aviation vehicles by Federal Aviation Administration Regulations, Part 147, Appendix B. A5.4 Maintain and document the maintenance of aviation and aerospace vehicles in accordance with the recommendations of the manufacturer. A6.0 Students understand the basic business practices of their employment environment: A6.1 Understand work-related systems of the aviation and aerospace industries. A6.2 Maintain accurate records for the pilot, tower, and so forth, as applicable. A6.3 Understand how guidelines, rules, regulations, and laws control aviation and aerospace industry practices and how they are overseen by local, state, federal, and international aviation agencies. A6.4 Understand the practices of acceptable customer relations services. A6.5 Understand the production and use of industry-generated documents, records, and forms as well as related management skills used in aviation and aerospace transportation industries. 357

- ❑ **Lesson Plan Relevance to Externship**
  The lesson plan follows the critical engineering path that is used to design and test the boosters, nozzles and fuel used in solid fuel rocket motor.

Description of Activities

(A ten-day lesson plan is not required)

- ❑ **Activity Day One:**
  Introduction to Autodesk Inventor.

- ❑ **Activity Day Two:**
  Design and save as .stl files – rocket booster fuel tank, rocket nozzles/s and plunge cast.

- ❑ **Activity Day Three:**
  Transfer .stl files to 3d printer and begin printing the parts.

- ❑ **Activity Day Four:**
  Insulate fuel Tank and Nozzle/s as needed.

- ❑ **Activity Day Five:**
- ❑ Make solid rocket fuel propellant and load fuel tank. Plunge cast while fuel is still soft.

- ❑ **Activity Day Six:**
  Assemble Booster with nozzle/s.

- ❑ **Activity Day Seven:**
  Place Booster on Test Bed and fire motor. Record results.

- ❑ **Activity Day Eight:**
  Retest if needed. If no retest, test on Rocket Car body (Rocket Car Body used from earlier design) and record results.

- ❑ **Activity Day Nine:**
  Retest if needed. If no retest, attach motor to Vertical Flight Rocket and fire. Record results – flight stability and altitude.

- ❑ **Activity Day Ten:**
  Review all data and make design changes as needed

Grading Rubric

Student Deliverables	1 Exceeds Expectations	2 Meets Expectations	3 Approaches Expectations	4 Fails to meet Expectations
Inventor Design Fuel Tank	Fits within Print Parameters with no modifications	Fits within Print Parameters with minor modifications	Fits within Print Parameters with multiple modifications	Fits within Print Parameters with significant modifications
Inventor Design Nozzle/s	Fits within Print Parameters with no modifications	Fits within Print Parameters with minor modifications	Fits within Print Parameters with multiple modifications	Fits within Print Parameters with significant modifications
Inventor Design Plunge Cast	Fits within Print Parameters with no modifications	Fits within Print Parameters with minor modifications	Fits within Print Parameters with multiple modifications	Fits within Print Parameters with significant modifications
3d Print Fuel Tank	Printed Part has no flaws	Printed Part has minor flaws that can be corrected without reprinting the part	Printed Part has flaws that require the part to be reprinted	Printed Part has major flaws that require the part to be redesigned and reprinted
3d Print Nozzle/s	Printed Part has no flaws	Printed Part has minor flaws that can be corrected without reprinting the part	Printed Part has flaws that require the part to be reprinted	Printed Part has major flaws that require the part to be redesigned and reprinted
3D Print Plunge Cast	Printed Part has no flaws	Printed Part has minor flaws that can be corrected without reprinting the part	Printed Part has flaws that require the part to be reprinted	Printed Part has major flaws that require the part to be redesigned and reprinted
Solid Rocket Motor Fuel	Meets mix Parameters with no	Meets mix Parameters with some variation	Meets mix Parameters with significant	Does not meet mix Parameters and requires

Assembly Test Bed, Rocket Car & Vertical Launch Rocket	Fits within Assembly Parameters with no modifications	Fits within Assembly Parameters with some variation	Fits within Assembly Parameters with significant variations	Does not meet Assembly Parameters and requires redesign
Testing Test Bed, Rocket Car & Vertical Launch Rocket	Fits within Testing Expectations with no modifications	Fits within Testing Expectations with minor modifications	Fits within Testing Expectations with multiple modifications	Does not meet Testing Expectations and requires complete redesign
Data Collection and Test Results Analysis	Data Collection and Analysis fits within DC & A Parameters	Data Collection and Analysis fits within DC & A Parameters with few errors	Data Collection and Analysis fits within DC & A Parameters with multiple errors	Data Collection and Analysis does not fit within DC & A Parameters – data not valid

Rocket Motors
Propelling Us to the Stars

Introduction to Rockets – Motors Unit

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Introduction

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- Stop watch
- Calculator
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Autodesk Inventor 3D CAD Software

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Conclusion

- The Manned Mars Mission is planned for 2030.
- Significant progress needs to be made to meet the timeline.
- You can be part of this mission.
- Ways to be a part of the mission are:
  - Chemist (Rocket Fuel)
  - Engineer (design of any components required)
  - Fabricator (Machining the parts required)
  - Assembler (Putting the vehicle together)
  - Tester (Testing components)
  - Many More!!!

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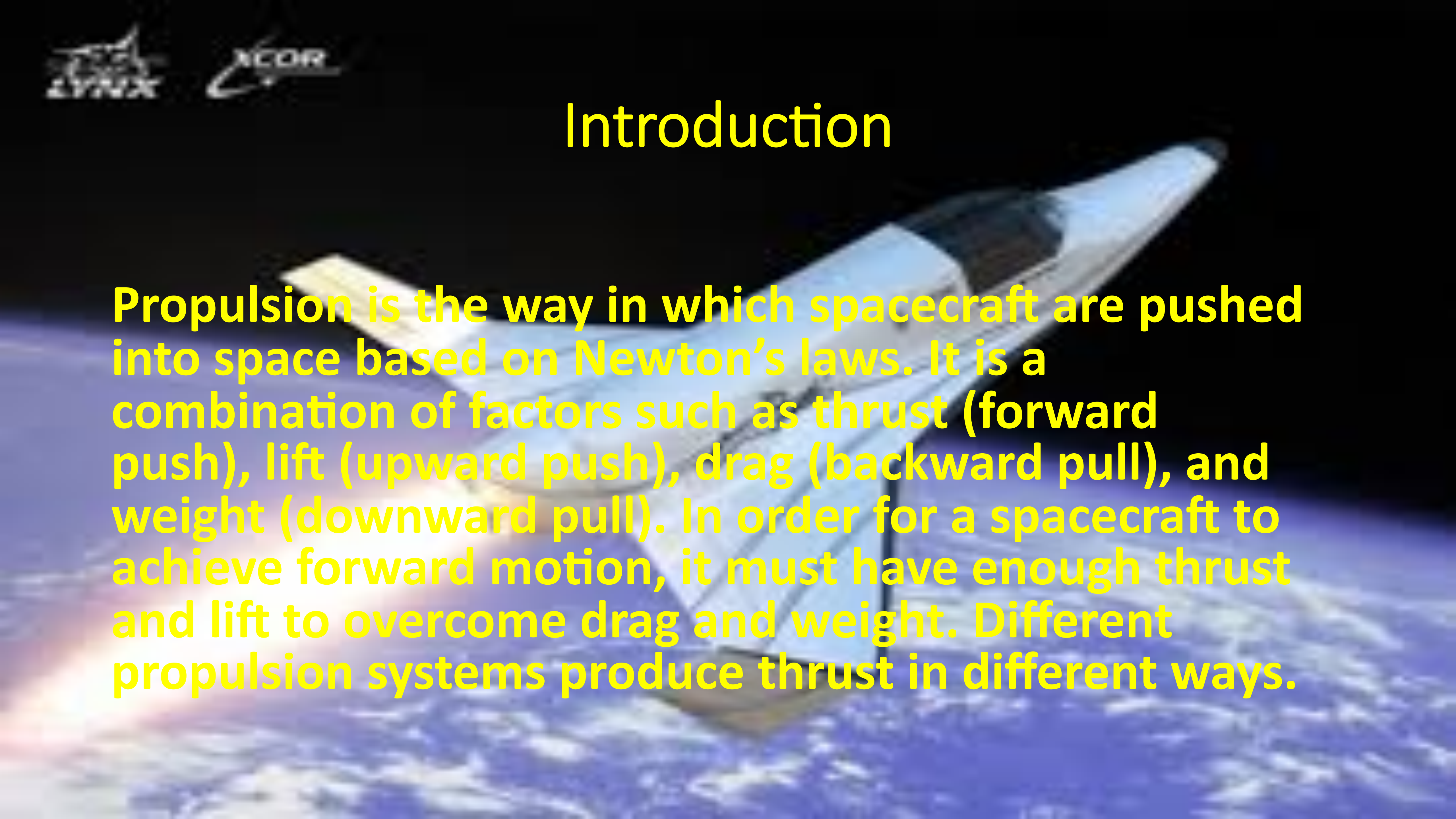

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Autodesk® Inventor®
Professional 2013

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Image courtesy of Brimrock Group Inc. and Mechanix Design Solutions Inc.

Autodesk

Solid Rocket Fuel

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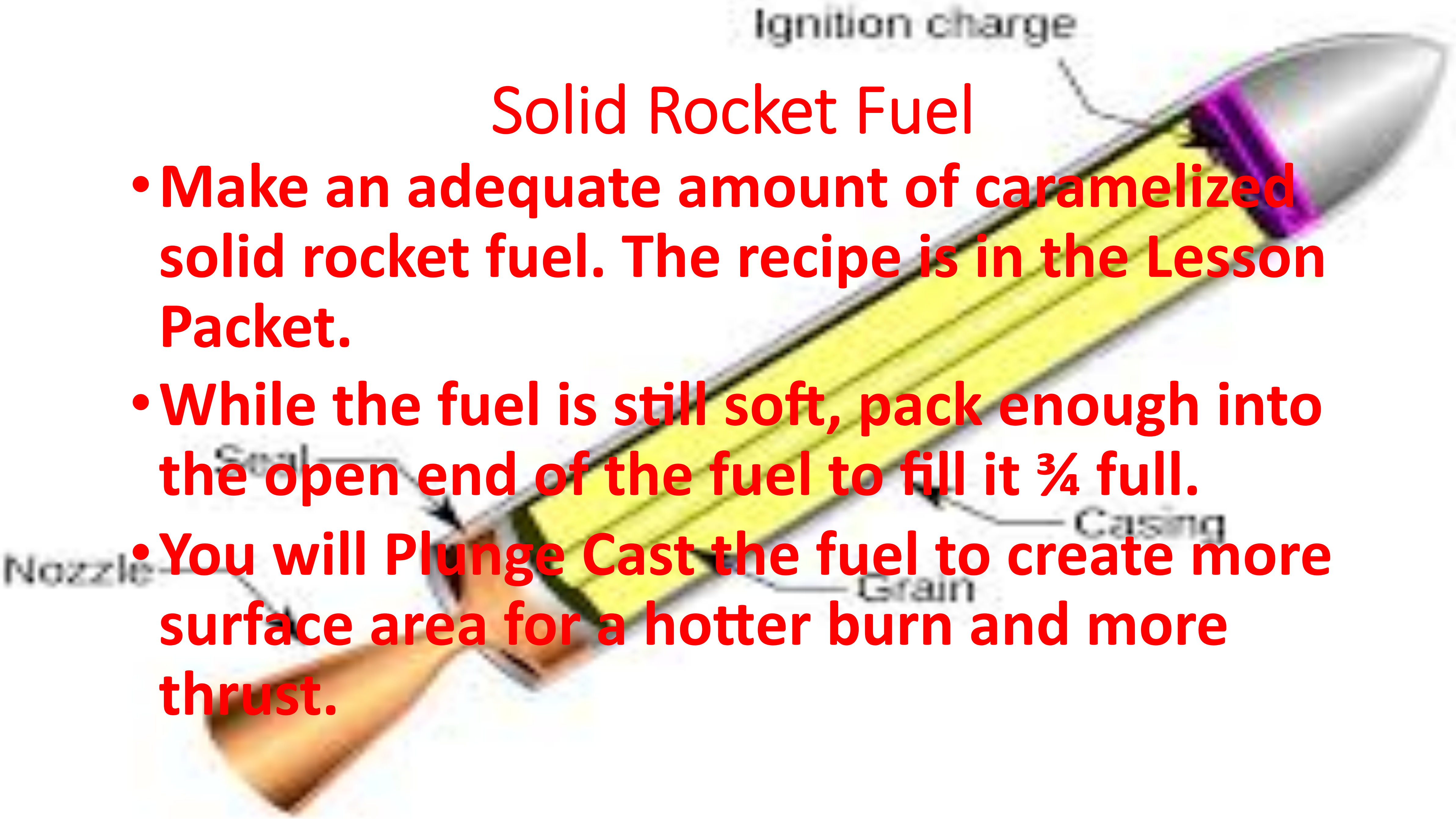

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